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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

INTERNAL
COMBUSTION
ENGINE VALVES

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Internal Combustion Engine Valves

A VALVE may be defined as a small mechanical device which is used for closing a passage. This definition is quite applicable to valves discussed in this article since it is essentially the function of a valve in an internal combustion engine to open and close a passage between the combustion chamber and the intake or the exhaust manifold.

Valves antedate the internal combustion engine by many years for they were required in the reciprocating steam engine from the very beginning. Although they are only a very small part of an engine and their cost is less than 5% of its total cost, they are among its most important parts, for without them the modern internal combustion engine simply cannot function. Their proper operation is essential to both good engine performance and fuel economy.

The subject of valves as a whole is so broad, that it cannot be completely treated in a short article. Therefore, the scope of this discussion will be limited to the more important aspects of the poppet type valves; their development, proper functioning and maintenance as they pertain to the internal combustion engine. The poppet valve is the type most commonly used in present day internal combustion engines. Other general types are sleeve and rotary, which will not be discussed at this time.

Although a great deal of the material presented in this article is of a general nature and pertains to the poppet valve in any type of internal combustion engine, some of the data pertains primarily to the automotive type engine.

DEMANDS ON VALVES

In order to better understand the problems encountered and which have to be surmounted to assure proper valve functioning, it is well to consider some of the demands imposed on valves in internal combustion engines. First of all, the valves are subjected to very high speed. For example, in a given eight cylinder car operating at 40 mph, the 16 valves open and close 840,000 times per hour. At even moderate speeds, the complete cycle of intake, compression, firing and exhaust takes place in less than 1/25 of a second, during which time the valves must open and close. This operation must take place in 1/100 of a second or less. During this cycle exhaust valves and seats are exposed momentarily to temperatures as high as 3800° F. normally operating at cherry red heat; even so they must maintain their hardness and form. These valves must also maintain their strength for although each valve weighs only about 5 oz. it must control and hold more than 14 h.p. and make a seal against pressures of up to 600 psi and greater. Also, they travel approximately ¼ mile in their guides for every road mile.[1]

Bearing these things in mind, it is readily understood why not only the highest quality in metallurgy and precision manufacturing, but also the greatest precision and skill in reconditioning and adjustments are required to assure good valve performance.

DEVELOPMENT OF VALVES

Progress in Design

As in the internal combustion engine in general, there has been a great change in valves from their early design to that used at present. These changes

[1]References given on page 84.

have been necessitated by changes in the engine such as increased compression ratio, greater power and speed, and fuel economy, all of which have made the function of valves increasingly more important, exacting and difficult.

Some of the major changes in valves have resulted from the intensive research of the metallurgists who have been able to develop valve metals which will withstand corrosion, abrasion, scaling, and burning, and not become distorted or lose their seating properties during severe operation. However, in spite of these advances and improvements made by the metallurgists, they have as yet to develop a perfect valve steel.

The demands on valves for different engines differ widely. Because of this, the metallurgist often has to resort to combinations of materials to obtain a satisfactory valve. For instance, one of the finest aircraft exhaust valves has a TPA austenitic steel base, a nichrome head coating, a stellite seat, nitrided stem, tool steel tip and sodium cooled hollow head.[2]

The metallurgist has been assisted by the automotive engineer who has continually improved engine designs so as to lessen the demand placed on the valves. Among the more pertinent contributions of the engineer are: sodium cooling, improved block and port design, efficient retainer locks, hard facing, good insert seat design, constant clearance regulators (hydraulic lifters), improved valve motion through cam design and positive valve rotation.

Sodium cooling has perhaps been the most outstanding advancement. It has been found very helpful in cases of chronic valve troubles. However, the installation of sodium-cooled valves must be accompanied by a thorough knowledge of the problem at hand for it may require the simultaneous modification of the seat, guide or other parts in order to obtain the maximum beneficial effect.

Nomenclature

Since there are some minor variations in the nomenclature used by various people for the valve and valve gear mechanism, the nomenclature shown in Figure 1,[1] which is perhaps the most widely used, will be adhered to throughout the subsequent discussion.

VALVE FAILURES

For the purpose of this discussion, the types of valve failures encountered in service may be classed as breakage and burning. The common causes for these failures are tabulated under each of these headings in Table I. In the following discussion, we will cover some of the more pertinent causes of failures, showing examples of some of them, and will endeavor to describe some methods which have been found effective in eliminating or reducing these failures. It is quite evident from Table I that the causes for these two types of failure are considerably overlapping and interrelated and that the occurrence of either one may be the cause of the other.

The first two items, valve material and design, listed in Table I as previously discussed, are problems which obviously must be handled by the valve and engine manufacturers who have conducted extensive research on them and therefore will not be discussed further in this article. Since the material and design of the valve itself are very closely related to these same items in the engine, the cooperation of the valve and engine manufacturers is essential to assure good performance.

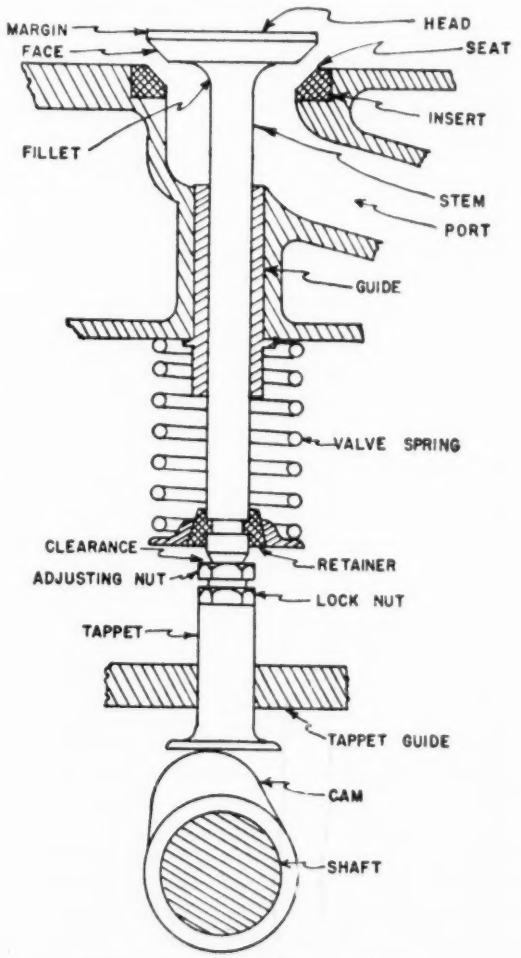


Figure 1 — Valve assembly nomenclature.

VALVE TEMPERATURE

Temperature is perhaps the most important single factor associated with valve life. It is more closely and directly related to either type of valve failure than any of the other factors, most of which tend to change valve temperature and thus indirectly influence failures. This is quite evident from the fact

TABLE I

Causes of Failure, Engine Poppet Valves

BREAKAGE

1. Unsuitable valve material.
2. Unsuitable valve type — to cure, consider
   a. Two piece type.
   b. Sodium cooled stem or head.
   c. Stellite faced.
   d. Copper cooled stem.
   e. Oversized stems.
3. Defective material or manufacture (forging cracks, slag or oxide inclusions).
4. Excessive valve temperatures — Usual causes:
   a. Lean mixture ratios.
   b. Valve head extending into combustion chamber too far.
   c. Poor seat condition, blowby at spots on seat.
   d. Poor stem condition.
   e. Poor guide condition.
   f. Insufficient tappet clearance.
   g. Excessive spring tension.
   h. Incorrect valve timing.
   i. Incorrect ignition timing.
   j. Full throttle operation.
   k. Excessive detonation.
   l. Excessive exhaust back pressure.
   m. Poor port, block, water passage and guide boss design.
5. Valve seat distortion.
6. Floating of valve assembly — Usual causes:
   a. Weak springs.
   b. Excessive engine springs.
   c. Operating engine in critical speed range.
   d. Excessive tappet clearance causing improper cam action.
   e. Valve spring surge.
7. Cooked valve springs or retainers.
8. Scratches on stem from improper cleaning methods.
9. Normal fatigue (limit of useful life).
10. Seat eccentric to stem.
11. No interference angle on seat.

BURNING

1. Unsuitable valve material.
2. Unsuitable valve and engine design.
3. Excessive valve temperatures (same as under breakage).
4. Full throttle operation (i.e. overloaded engines).
5. Part throttle operation (i.e. lean mixtures).
6. Valve stem stretching — Usual causes:
   a. Excessive temperature.
   b. Incorrect material.
   c. Over-strong springs
7. Valve seat distortion — Usual causes:
   a. Mechanical distortion during installation or retightening heads (substitution of solid copper for copper-asbestos gasket often helpful).
   b. Insufficient or unequal cooling (jacket deposits, defective cylinder casting).
   c. Differential expansion (consider use of interference angle with prevention of valve rotation).
8. Warpage of valve head.
9. Warpage of valve stem.
10. Forging of valve seating surface — Usual causes:
    a. Unsuitable stem material.
    b. Lacquer deposits.
    c. Insufficient clearance between stem and guide.
11. Insufficient tappet clearance — Heavy duty, full throttle service may require up to 50% more clearance.
12. Valve head and seat materials not compatible ("warts" or "pickup").
13. Too infrequent service checks.
14. General maintenance.

that failure of intake valves, which usually operate at appreciably lower temperatures than exhaust valves, are relatively minor compared to exhaust valve failures. As indicated in Table I, a number of factors have an effect on valve temperature.

Both the design of the valve itself and some of the valve gear such as guide boss, port passages, and water passages in the head and block have an appreciable effect on valve temperature. In addition, certain operating conditions affect valve temperature appreciably, for instance, the fuel-air ratio as illustrated in Figure 2,[3] from which it may be noted that valve operating temperatures are dependent upon fuel-air ratio, reaching a peak at approximately the theoretical chemically correct mixture and decreasing linearly for both leaner and richer mixtures. Since most operation is at the most economical mixture which is just slightly richer than the theoretical value, the valves are generally operating at peak temperatures from the fuel-air ratio standpoint, providing other conditions remain unchanged.

Valve operating temperature also increases with increased engine speed and load; the former having the most influence. Some of the other factors which are also associated with valve temperature will be discussed separately later in this article.

VALVE HEAD

A fairly heavy head on the valve is necessary to give it sufficient strength and heat dissipation. However, too much of the valve should not extend into the combustion chamber for this may result in considerable overheating. When the valve has been faced down so that a knife edge results on either part or all of its circumference, it may lead to breakage and burning due to its weakened condition and may also cause preignition due to localized heating on the edge. This may also result in cupping of the valve. Accordingly, when refacing brings the margin below 3/64 in., it is generally the best practice to replace the valve with a new one.[4]

VALVE FACE AND SEATS

The valve face and seat are perhaps the most critical parts, for it is here that the seal between the valve and block or head must be made to prevent the flow of gases. A number of the more pertinent factors which must be considered in connection with the valve seats will be discussed separately in the following paragraphs.

Seat Width

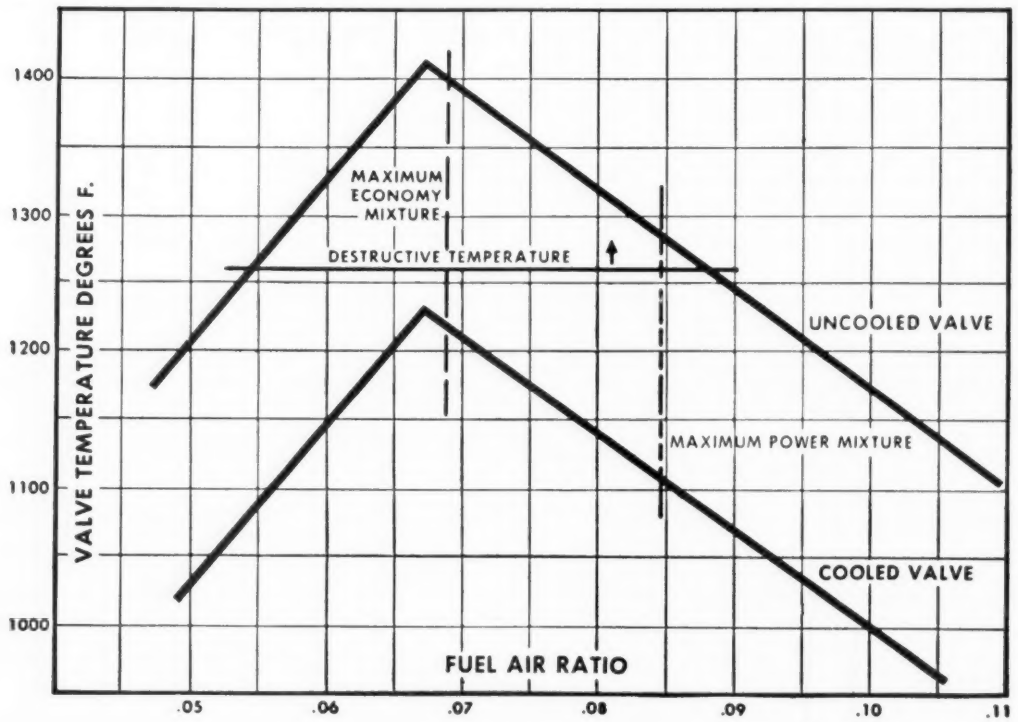
The correct width for valve seats varies with the size of valve and the condition under which it operates, and therefore it is difficult to set up a standard specification for width. However, in general, it is good practice to maintain the seat width specified by the engine manufacturer. Seat widths in the range of 5/64 to 9/64 in. are recommended for many engines. Too wide a seat tends to collect and allow accumulation of carbon and other hard particles of deposits, while too narrow seats reduce the rate of heat dissipation into the jacket coolant which may result in overheated valves.

Interference Angle

In some cases where valve burning is difficult to overcome, it has been found very satisfactory to use an interference angle of ¼ to 1°, that is, the valve is faced at an angle ¼ to 1° flatter than the seat angle as illustrated in Figure 3. This exerts greater pressure on the upper edge of the valve face and tends to give a better seal.

Incompatibility of Valve and Block Seat Material

When the material in the valve face and the seat are not compatible, a phenomenon occurs which has been described by such terms as "pickup", "warts" or "block pounding". What occurs in such cases is that the structure of the seat material under certain extremely high temperatures changes with resultant softening. When the valve comes in contact with the softened seat surface, little balls of iron are rolled up from the seat and stick to the valve. This can generally be overcome satisfactorily by the use of hard valve seat inserts.



Courtesy of Eaton Manufacturing Co.

Figure 2 — Showing relation of fuel air ratio to valve temperature.

Worn and Pitted Seats

When severe seat wear occurs, particularly on intake valves, it is generally an indication that the air cleaner is not performing satisfactorily. Seat pitting occurs when hard particles have come between the seat and valve face and are pounded into the seats which may become softened somewhat due to the high temperature. It is very difficult to prevent this occurrence except by the use of stellite seats, but it can be corrected by refacing.

Seat Distortion

Both hot and cold valve seat distortion are en-

countered in service. Cold distortion generally results from improper or uneven tightening of the cylinder head bolts.[5] Hot distortion as the term implies, results from overheating during operation which may be caused by such conditions as listed

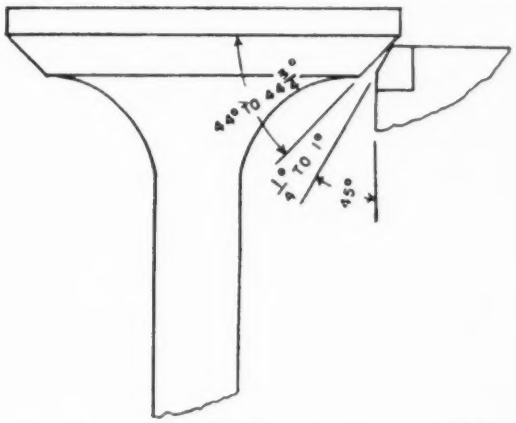


Figure 3 — Exaggerated illustration of interference angle.

in Table I, under valve temperatures. Either of these types of distortion may result in warped valve stems and poor seating of the valve in its seat as illustrated in Figure 4.

VALVE STEMS

The main difficulties associated with the valve stem are stretching and distortion. These are generally both directly attributable to high temperature which might result from any one or a combination of the items discussed under valve temperature, or in some cases to poor valve material or design. Either stretching or distortion of the stem may result in poor seating due to lack of concentricity between the valves and seat. The concentricity of the valve face to stem should generally be kept at a minimum and within 0.003 in. total run out.

VALVE GUIDES

Clearances

The main function of the valve guide is to maintain perfect alignment between the valve face and seat so as to form a perfect seal. In order to accomplish this function, proper stem-to-guide clearances must be maintained. Too large clearances will cause a valve to "wallow out" the seat, while too little clearance will result in valve sticking at high temperatures. The stem-to-guide clearance generally increases with the stem diameter and may vary with different types of engines. However, a safe general rule to follow for exhaust valves with alloy steel stems is to allow 0.001" clearance per 1/8" stem diameter, while intake valves should operate with a clearance of 0.001" per each 3/16" stem diameter. The generally recommended average clearances for various size valves are shown in Table II.

Alignment

In addition to proper stem-to-guide clearance, it is also essential for the guide to be concentric with the seat. The concentricity between the seat and guide should be within ±0.001" and may be attained by proper grinding of the seat. Valve stems should also be smooth to avoid excessive wear of the guide with resultant increased clearances and bell mouthing. Some difficulty due to corrosion may also be encountered in certain bronze exhaust valve guides. This may generally be minimized by reducing the operating temperature of the valve guide.

Bell Mouthing

Bell mouthing of the guides due to wear is another difficulty encountered in the guide and is generally caused by expansion of and warping or distortion of the valve stem, guide or seat (See Figure 5). Since the guide expands at high temperature, the pocket or bell mouth will open so that deposits can collect in it. Then on cooling and contraction the valve stem will become pinched and result in sticking valves and subsequent burning.

TAPPET CLEARANCES

Maintaining correct valve tappet clearances is considered by some as the most important maintenance item. If the clearances are too small, the valve will not close properly when hot, thus permitting blowby of hot gases with resultant burning. If the clearance is too great it will tend to upset the timing, shorten valve lift above the seat, preventing maximum intake and exhaust, and the ramp portion of the cam will be inoperative causing the valve to be lifted and seated with terrific impact resulting in excessive loads and eventual breakage. Proper clearances vary with different engines and it

TABLE II

Valve Stem-to-Guide — Average Clearance*

Nominal Dia.	Inlet, in.	Exhaust, in.
5/16	0.0015–0.0035	0.0015–0.0035
11/32	0.0015–0.0035	0.0015–0.004
3/8	0.0015–0.0035	0.002 –0.004
1/2	0.002 –0.004	0.003 –0.005
5/8	0.0025–0.0045	0.004 –0.006
3/4	0.003 –0.005	0.005 –0.007
7/8	0.004 –0.006	0.006 –0.008
1	0.0045–0.0065	0.007 –0.009
1-1/8	0.005 –0.007	0.008 –0.010
1-1/4	0.0055–0.075	0.009 –0.011
1-3/8	0.006 –0.008	0.010 –0.012
1-1/2	0.007 –0.009	0.011 –0.013
1-5/8	0.0075–0.0095	0.012 –0.014

*(References 4 and 6.)

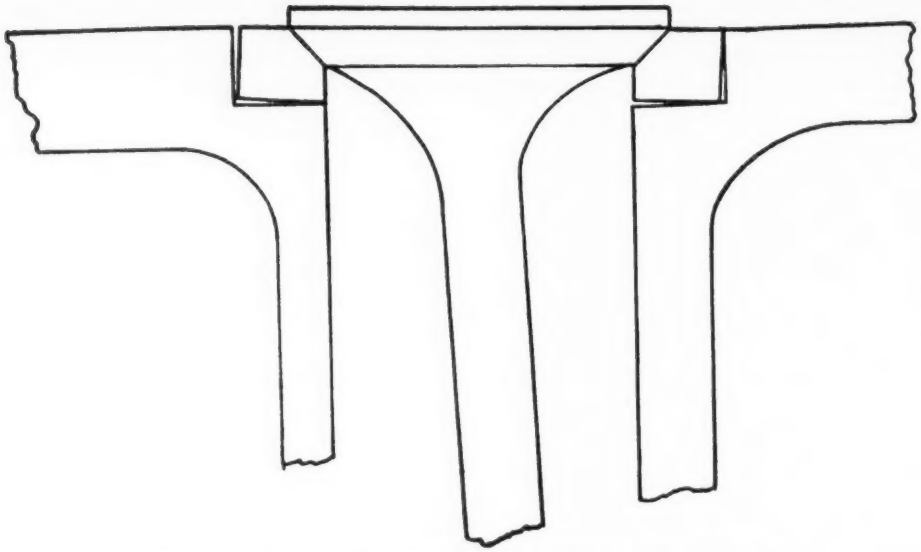


Figure 4 — Exaggerated illustration of warped valve and seat distortion.

is therefore advisable to closely adhere to the engine manufacturer's recommendation since he has performed a great deal of experimental work to determine the proper clearances.

Of the various types of valve tappets in use, i.e., the non-adjustable, the common adjusting screw with lock nut, the self locking screw and the zero-lash hydraulic valve lifter, the latter is the only self-adjusting type. Hydraulic valve lifters are available for both the L head and valve-in-head engine. Their operation is simple, positive acting and automatically adjusting to compensate for expansion and contraction in the valve train. Although their initial cost is somewhat higher than for the other types their performance from the standpoint of more silent and better engine operation, longer valve life, and less service attention is far superior.

VALVE SPRINGS

To assure good valve operation, the spring must perform its function perfectly, which is to hold the valve face tightly against the seat until forced open by the cam or tappet. In order to do this the spring must have the correct tension. A spring which is too weak will allow the valve to flutter and be thrown from the cam and not follow it at higher speeds which will cause excessive bounce and impact with resultant failure. A spring which is too strong will cause valve stretching with resultant over-heating and eventual burning and failure. It is advisable to check the spring tension at its operating length whenever servicing valves. If springs are only slightly weak, this can sometimes be corrected by placing a thin shim (1/16") between the springs and the seat in the block or head. In fact, some operators have found it very satisfactory to shim the spring in this manner whenever refacing valves to compensate for the lengthening of the valve stem due to removal of metal from the valve face and seat.

In addition to having proper tension the valve spring must have smooth, even and square ends, also when installing they must be checked to ascertain that the spring or retainer is not in a cocked position, for either of the foregoing would result in side thrust on the valve stem which would cause distortion, uneven wear of the stem and guide, and poor seating, with resultant blowby and failure.

VALVE TIMING

Proper timing of both the exhaust and intake valves is essential if maximum power and efficiency are to be obtained. This also has an important bearing on valve life. An intake valve opening too early will allow the intake mixture to become contaminated with exhaust gases, while an exhaust valve opening too early will not allow complete expansion and cooling of combustion gases on the power stroke. Late opening of the intake valve reduces the quantity of intake mixture entering the cylinder, while late opening of the exhaust valve does not permit complete discharge of exhaust gases and results in reduced compression pressure. All of these factors contribute to reduce power and efficiency as well as increased valve temperature and thus reduce valve life.

IGNITION TIMING

Ignition and valve timing must be closely coordinated and must occur at the proper point in the cycle to give maximum power and best performance. With early ignition maximum pressure occurs

too early in the cycle and results in loss of power. With too late ignition, maximum pressure is not reached early enough to overcome the increased volume caused by the receding piston, thus resulting in loss of power. The latter condition can be much more injurious to exhaust valve parts than the former since the burning gases pass through the valve opening before sufficiently cooled due to expansion. Incorrect ignition timing might also result in detonation and preignition, which have an appreciable effect on valve temperature and life.

CARBURETION

Improper carburetion will not only reduce power and efficiency and give generally poor performance, but will also appreciably affect valve life. As pointed out earlier fuel-air ratio has an appreciable effect on valve temperature and thus on valve life. In addition, rich mixtures will foul spark plugs, waste fuel, form excessive deposits, dilute lubricants and cause roughness at low speed.

DEPOSITS

Excessive deposits on any part of the valve or stem may prevent proper seating which would result in blowby, excessive temperature and resultant burning and valve failure. Deposits are more or less indirect causes of failure since they are generally a result of some other factor or combination of factors as indicated in Table I. Deposits may vary in nature from a soft gummy to hard carbon and lava-like substance, depending upon the condition responsible for their formation. In many instances their nature aids considerably in diagnosing their cause. Since the factors influencing intake and exhaust valve deposits vary considerably, they will be discussed separately.

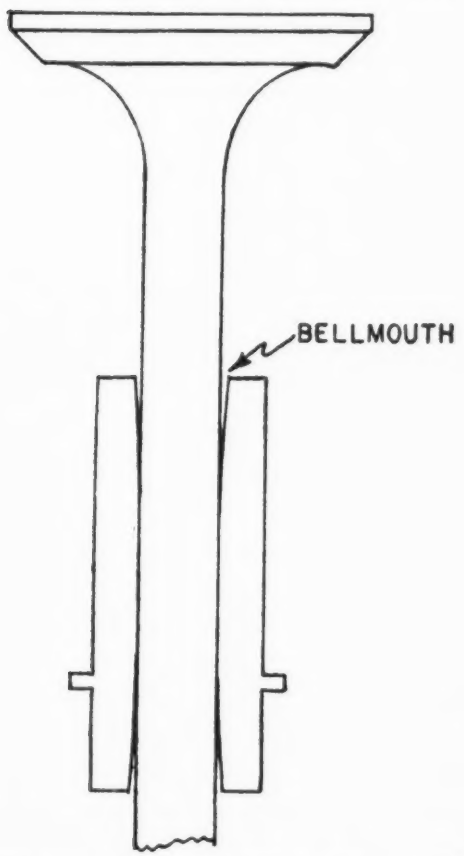


Figure 5 – Exaggerated illustration of "bell mouthing" of valve guide.

Intake Valve Deposits

Excessive gum in gasoline may produce heavy gummy deposits on the upper portion of the intake valve stem and fillet under certain types of operation, particularly in winter or under "stop-and-go" driving conditions. When fuels leave the refinery, the gum content must be below a certain specified safe limit. However, the long storing of certain fuels may result in an appreciable increase in gum content. The rate of formation of gum in fuels during storage is greatly accelerated by certain catalysts such as copper in the fuel line and tanks and soldering fluxes which may be present in a new tank.

In Figure 6 are shown the type of intake valve deposits obtained on a laboratory dynamometer test engine after 224 hours of operation under fairly severe conditions on a fuel with an abnormally high ASTM gum content.

Improper carburetion resulting in poor combustion and repeated backfiring, as well as worn guides, poor seating, and excessive leakage past the valves may also contribute to deposit formation. In addition unstable oil, too little oil or too much oil resulting from excess carry-over from the oil bath air cleaner, may affect valve deposits. Introduction of dirt and foreign matter through the air intake due to a dirty or otherwise improperly functioning air cleaner or no air cleaner at all will also increase deposit formation.

Oil which is very unstable or too long a period between oil drains also may tend to aggravate deposit formation. This may be particularly true under low engine operating temperatures.

Exhaust Valve Deposits

Exhaust valve deposits are greatly aggravated by poor condition of the valve guide such as a bell-mouthed, sloppy or worn guide, too small a valve stem-to-guide clearance, or guides extending too far into the valve port. Worn and sloppy guides allow oil to fill in the space between the stem and the guide, and to stew there and become cooked or cintered into a hard mass of carbon which eventually holds the valve off the seat. Guides extending

into the ports too far allow the stem to become heated excessively and thus aggravate the formation of deposits. This condition can be minimized appreciably by cutting the valve guide back square and sharp so that it does not extend into the valve port too far. Valve guide material which is too soft may also be an indirect factor since it allows excessive wear.

VALVE MAINTENANCE PRACTICES

The importance of good valve maintenance practices cannot be over emphasized for, regardless of how perfect the design, and materials, if the valve is not installed or adjusted properly, failure will result. Some of the items which rightly belong in the category of maintenance have already been discussed, but will again be pointed out and emphasized here.

Servicing

Many of the causes of valve failure discussed in the preceding section of this article can be eliminated, or at least minimized, through proper maintenance practices. The more pertinent of these items are discussed in the following paragraphs.

One of the first essentials to insure proper valve functioning and maximum valve life requires that periodic checks be made to ascertain the general valve condition.

Periodic service checks of valve tappet clearances and compression pressures, which are readily made, will generally indicate if further more extensive servicing is required.

After valves have been in operation for some time and are removed for servicing, they should be checked for wear on the stem, straightness of the stem, valve face and seat condition. If necessary, they should be refaced.

In addition, it is desirable to make periodic checks on the carburetion system, and valve and ignition timing. As previously pointed out ignition and valve timing must be closely coordinated for which the use of a timing light is essential.

Refacing

Refacing the valve and seat is one of the most important operations in proper valve maintenance and, perhaps, requires the greatest skill of all. Refacing may be performed in an engine lathe equipped with a tool post grinder, or on one of the various types or makes of valve refacers. In every case it is essential that the refacing equipment be operated and maintained properly and in accordance with instructions generally supplied with the refacing equipment. For instance, the use of a dull or loaded grinding wheel for refacing a valve may result in "grinding checks," (numerous hairline cracks) on the valve face, which will eventually lead to valve burning and failure. These cracks apparently result from intense local heating and subsequent cooling at the region of contact between the wheel and valve face, especially with a dull or

Figure 6 — Intake valve deposits after 224 hours operation on dynamometer with fuel of abnormally high ASTM gum.

loaded wheel, and are fine enough so as not to be visible to the naked eye. However, they are quite evident under magnification, as illustrated by the photographs in Figure 7, which show a refaced valve seat taken at seven magnifications.

These cracks serve as the foci for stress concentrations and can be produced by refacing operations not sufficiently severe to blue the valve face. This condition, plus cycling and uneven high temperature operation, pounding and deposit formation apparently starts the burning action along these cracks, which eventually develops into guttering and further cracking followed by complete burning and breaking away of sections of the valve head. The photographs in Figure 8, taken at five magnifications, illustrate the various stages of cracking and burning that have been found in exhaust valves, while those in Figure 9 taken at normal size, show examples of valves from service exhibiting various stages of cracking and burning.

Normally, in refacing valves, the valve face angle should exactly match the seat angle. However, when guttering (washing out of a trench across the valve face) is occurring during operation, the use of an interference angle previously discussed has been found helpful. In addition, when refacing valves, they should be checked for concentricity of the valve face to stem, which should be held within 0.003" total run out.

Grinding

In some instances, it may be necessary to lap or grind the valve face and seat with grinding compound. However, in general, it is advisable to keep away from this practice if possible, particularly with alloy steels of the high heat resisting type, which having a greater coefficient of expansion than the low alloys or cast iron, consequently will not seat in the same position when hot as when cold. Therefore, after a groove is ground into the valve face due to the abrasive action of the grinding compound, the valve will probably ride on the resulting ridge with poor seating when operating at normal temperatures.

In case it is necessary for the valve to be lapped with a grinding compound, it is advisable to rotate the valve against the seat with minimum pressure (no more than the weight of the valve) and by means of a tap wrench or lathe dog fastened to the stem at the end opposite the head. This will assure the same alignment with the guide as when in normal operation. Used grinding compound should be removed frequently and fresh compound applied.

Valve Seats

The use of removable valve seat inserts has become general practice by many engine manufacturers in the past few years. Since the major part of the heat from a valve is transferred through the seat, and any air spaces between the seat insert and head or block will greatly reduce the heat transfer, it is essential that they be installed correctly. In an effort to maintain maximum heat transfer, some manufacturers furnish their seat inserts with a smoothly ground finish on the outside surface.

Since the details of installation of the various makes of seat inserts differ, it is generally the best practice to follow the instructions supplied by the manufacturer as to removal, installation and press fit allowances.

After installation of the seat insert, it should be ground to the proper seat angle so that its concentricity with respect to the guide will be within the required limits, as determined by the dial test indicator generally furnished, with grinding equipment, for this purpose. In this connection, it may also be found helpful to use a dummy head or block, depending on the type of engine, which can be drawn down so as to set up any strain which will be present when the head is actually installed.

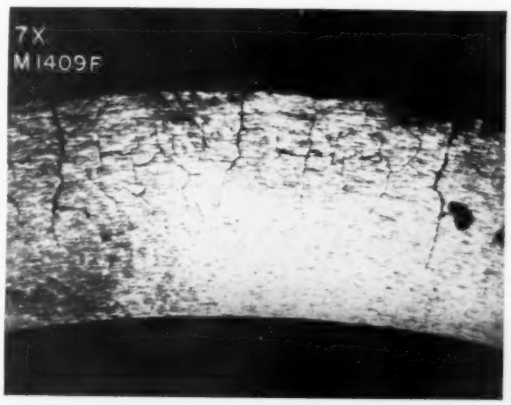


Figure 7 — "Grinding checks" due to improper valve refacing (7 magnification).

In regrinding seats which have been in service for some time, it may, at times, be necessary to remove sufficient metal to bring the seat into concentricity with the guide so that it will become wider than the valve face itself. When this occurs, the seat should be narrowed down by the use of a grinding wheel with an angle approximately 15° flatter than the seat angle; being narrowed sufficiently so that the upper seat diameter is at least 1/16" less than the upper valve face diameter.

Valve Guide

As in the case of removable seat inserts, most present day engines are equipped with removable valve guides. The importance of proper valve guide clearances and their effect on valve life have previously been stressed; therefore, this discussion will be primarily devoted to the proper method of installation. In general, it is good practice to check

and replace worn guides at regular intervals and replace those which have been worn so that the clearances are more than twice that specified for new parts.

The first step in the replacement of a valve guide should be to check the guide bore in the cylinder block, head or cage to determine if it is worn appreciably and, at the same time, determine if the guide has the correct interference or press fit. The guides should have a good press fit, but not so great as to cause breakage of the guide or to distort the valve bore itself, which would result in valve sticking. A safe general rule to follow is to allow 0.001" press fit per inch guide diameter. Generally, it is desirable to extend the guide well up to the valve head, however, it should not be allowed to protrude appreciably beyond the guide bore, since it will become overheated, with resultant distortion, bell mouthing, and poor valve operation.

After the guide has been installed it should be reamed with a suitable reamer to the exact inside diameter to assure the correct valve guide-to-stem clearance.

In some cases, where the guides extend beyond the guide bore and poor performance results due to guide distortion and deposit formation, it has been found very helpful to cut the guide off flush with the bore, as illustrated in Figure 10.

Valve Springs

The effect of too weak, too strong or otherwise defective springs on valve life has been previously discussed. The importance of checking springs at the time of each valve servicing should, however, again be emphasized. Valve spring testers for determining spring compression pressures are available commercially. However, if a regular tester is not available, a small platform scale may be set up under a drill press or a lever hinged at one end, as illustrated in Figure 11 which can be used to determine the pressure required to compress the spring to the length it would have when installed and the valve is in either a fully open or closed position. Although the exact compression pressures for all springs are not given here, they are available from engine or spring manufacturers. When these are not

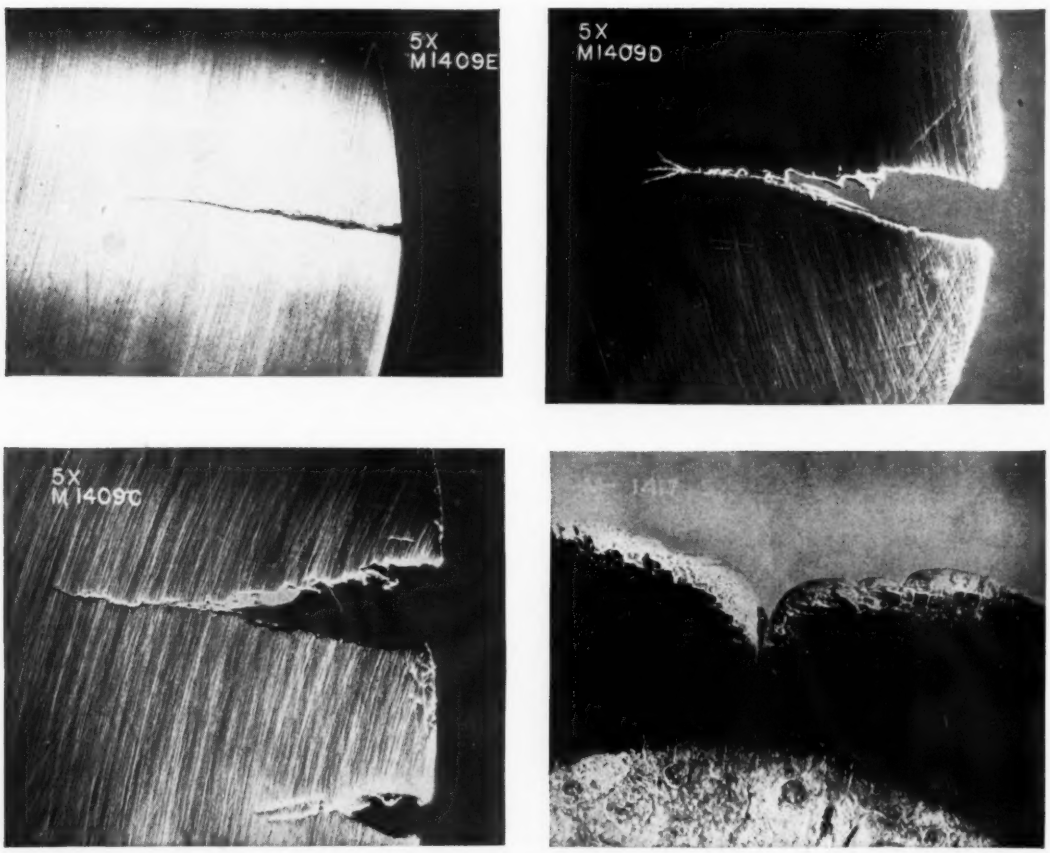


Figure 8 — Various stages of exhaust valve cracking and burning (5 mag.).

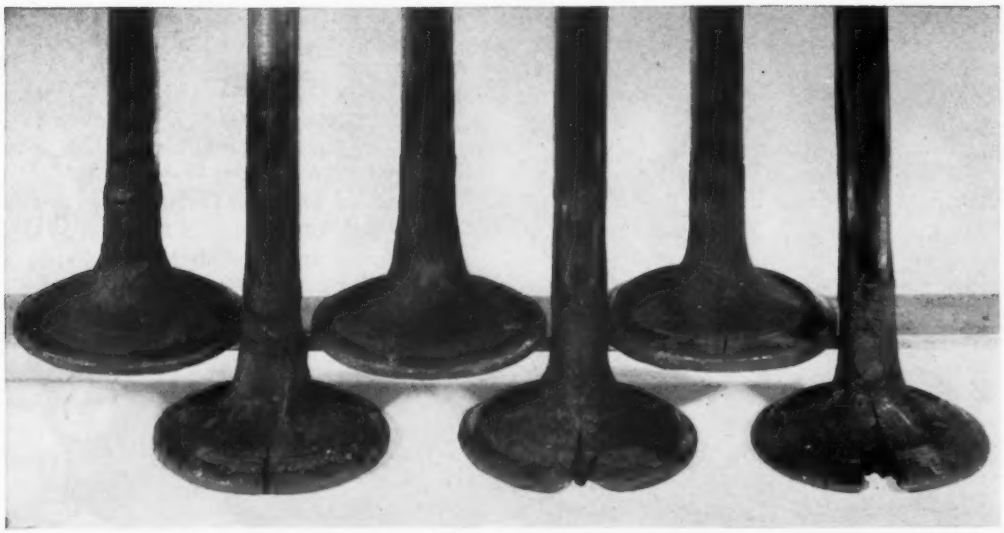


Figure 9 — Exhaust valves from service exhibiting various stages of burning.

available, a safe rule to follow is to check all new springs before installation and not use any springs that deviate from the average by more than 10%. Similarly, any old springs showing variations of more than 10% from the average value of the new should be replaced.

Cylinder Head Tightening

The proper tightening down of the cylinder head during valve servicing can make the difference between a satisfactory or unsatisfactory job for, as previously pointed out, distortion of the valve seat can result from the incorrect procedure of installing the cylinder head and gasket and tightening down of the head. A number of recommended procedures prevail. Most engine manufacturers have their own recommended procedure so that it would be impossible to cover them adequately in this article. However, there is one thing all these procedures have in common, and that is the cylinder head bolts should be drawn down evenly and in a definite order or sequence. This should be done gradually, first making all bolts finger tight, then tightening lightly with a wrench, then drawing down snugly, preferably with a torque wrench to a given torque

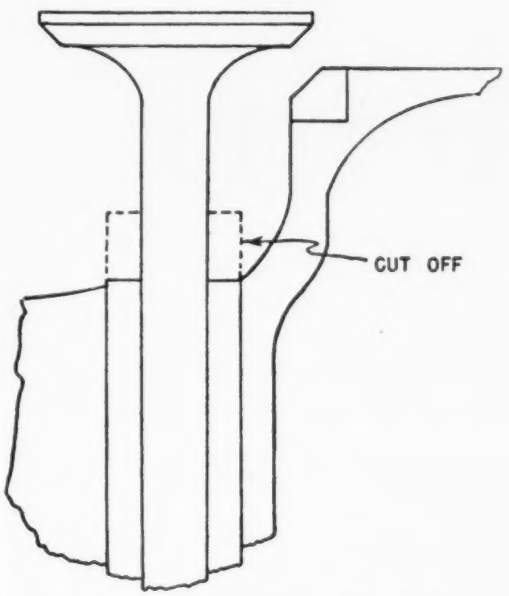


Figure 10 — Illustration showing cut-off guide.

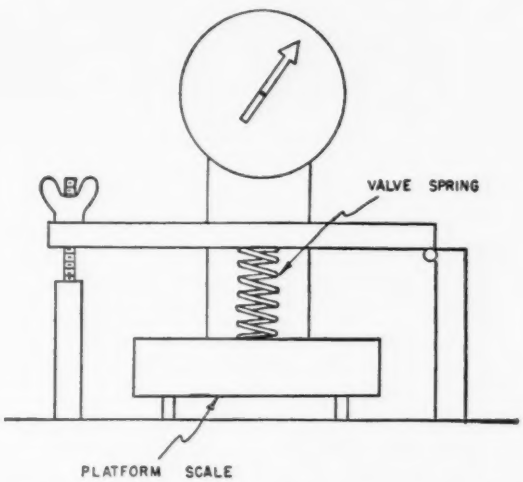


Figure 11 — Simple device for determining valve spring compression pressures.

setting, which should be repeated after the engine has been warmed up to normal running temperature. Figure 12[6] illustrates typical recommended sequences of tightening cylinder head bolts for a head with two and also three rows of bolts.

SUMMARY

Proper valve functioning is essential for efficient and satisfactory engine performance.

In order to assure good valve operation a number of factors must be taken into consideration.

1. The valve and related parts must be made of the proper material and have the correct design.

2. The many factors which contribute to valve failure either directly, or indirectly by increasing valve temperature must be given careful consideration and corrective measures taken when valve troubles arise.

3. The use of a good grade of fuel and lubricating oil is added insurance for good valve and general engine performance.

4. Valve failures can be greatly minimized and in many cases eliminated completely through proper servicing and maintenance practices.

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Acknowledgment is hereby given to the following from which ideas, information and sketches either in part or whole have been obtained:

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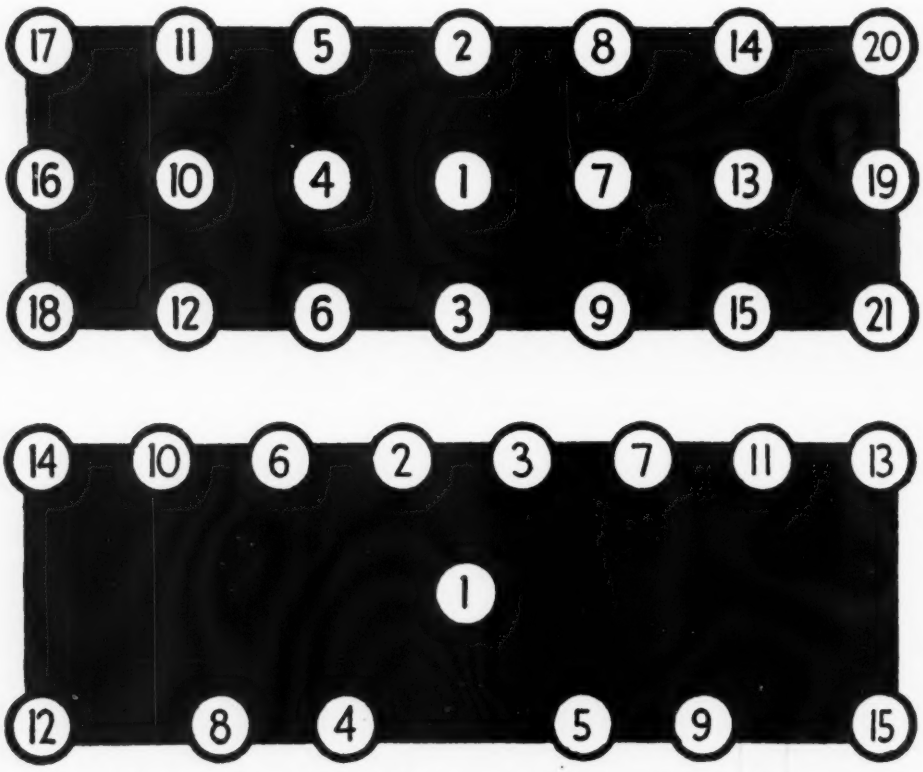

Figure 12 — Diagram showing typical sequence for tightening cylinder head bolts.

Above: For DeSoto. Below: For Chevrolet.

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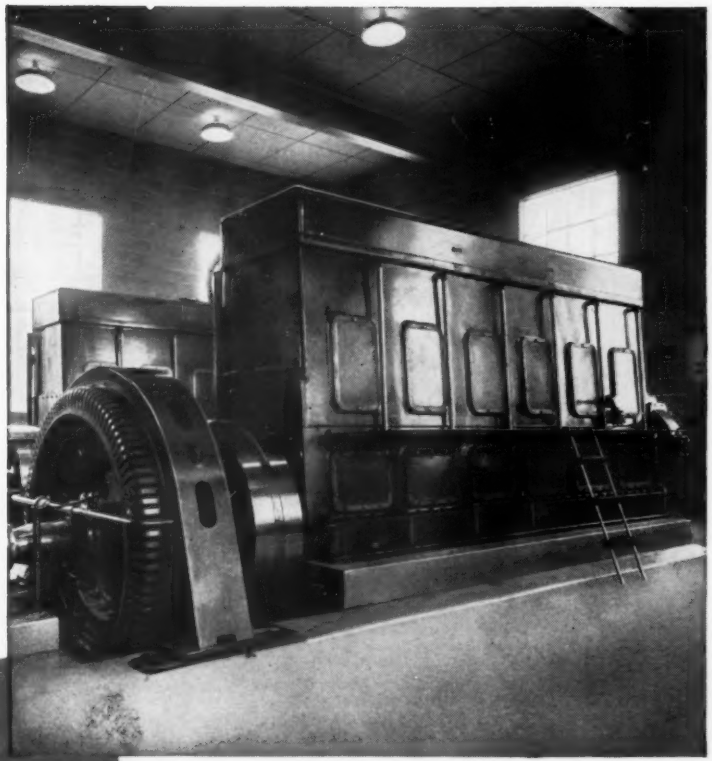

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